IMPROVING SUBGRADE SUPPORT VALUES WITH LONGITUDINAL DRAINS

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INTERIM REPORT

FOR

MATERIALS LABORATORY RESEARCH

PROJECT MLR-84-3

IMPROVING SUBGRADE SUPPORT VALUES

WITH

LONGITUDINAL DRAINS

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INTRODUCTION

This report is a brief summary of research being conducted under the direction of Charles Potter, Special Investigations Engineer, and Kermit Dirks, Soils Geologist. Present plans are to publish a more detailed report covering this research during 1984.

Prior to 1976, Iowa DOT pavement structural testing was conducted using a Benkelman Beam to determine static deflections resulting from an 18,000-pound axle load. This data had been adequate for structural analysis but testing was slow and did not relate to dynamic loadings.

IOWA DEPARTMENT OF TRANSPORTATION ROAD RATER

The Iowa DOT purchased a Model 400 Road Rater from Foundation Mechanics Division of Wylie Laboratories in 1976. The Road Rater is an electronically controlled, hydraulically powered unit mounted in the rear of a van-type vehicle (figure 1). A servo valve allows a pulsating flow of hydraulic fluid that imparts a movement into a large mass mounted in the center of the unit. The resultant movement of this mass produces a force that is applied to the pavement. This dynamic loading was initially set to vary from 800 to 2,000 pounds. The force being applied to the pavement is monitored by velocity sensors. The Road Rater electronic controls easily allow for a variation of the applied load and the frequency with which the load is applied.

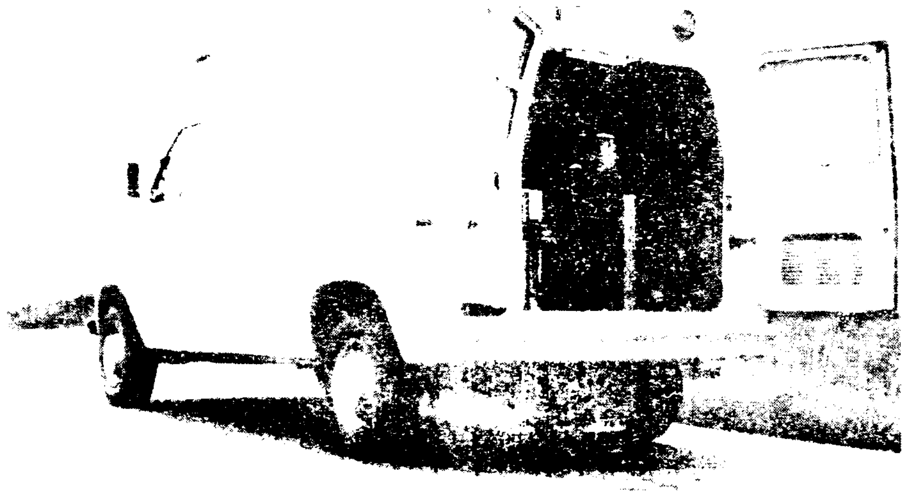


Figure 1. The Iowa DOT Model 400 Road Rater

The Road Rater was primarily used for evaluation of flexible pavements through 1962. A dynamic loading varying from 800 to 2,000 pounds on a frequency of 25 cycles per second was used for testing of flexible pavements. Road Rater data yielded a correlation coefficient of 0.83 when compared to Benkelman Beam results.[1]

When the Iowa DOT expressed a desire to increase the Road Rater output to test rigid and composite sections, the manufacturer was very cooperative. The formula to determine the peak to peak force output is:

$$F = 32.7\ f^2\ D$$

F is the peak to peak force in pounds.

f is the frequency of the loading in Hertz.

D is the peak to peak displacement of the mass in inches.

The Road Rater standard output for flexible pavement testing is:

$$F = (32.7)(25)^2(0.058)$$

$$F = 1185 \text{ pounds}$$

The manufacturer's recommended maximum output for rigid and composite pavement testing was a mass displacement of 0.068 inches and a frequency of 30 Hertz. The resulting output is:

$$F = (32.7)(30)^2(0.068)$$

$$F = 2000 \text{ pounds}$$

This output was not available for the correlation with the FHWA "Thumper." This output was used extensively for rigid and composite section testing in 1983.

CORRELATION OF THE IOWA DOT ROAD RATER WITH THE FHWA "THUMPER"

Due to economic limitations, recent trends have been away from construction of new roadways with a greater emphasis on the rehabilitation of present roadways. This generates a need for determination of roadway support ratings for rigid and composite sections. Research was initiated to determine if the Road Rater could be used to obtain structural data from these sections.

The Federal Highway Administration has developed a pavement deflection test system named, "Thumper." The Thumper will apply loads -- either static or dynamic -- up to 9,000 pounds to a roadway surface and record the resulting deflections from sensors on that surface. In April, 1982, the Iowa DOT Road Rater was correlated with the FHWA Thumper on 39 different structural sections[2] ranging from 10" of portland cement concrete pavement or 25" of asphalt pavement to a newly graveled unpaved roadway. A high correlation between the 9,000-pound Thumper deflection and the 1,185-pound Road Rater deflection was obtained (figure 2).

The FHWA tested most of the 39 different structural sections at 3,000-pound, 6,000-pound and 9,000-pound inputs. It was interesting to note that the resulting deflections from these load applications exhibited almost a straight line relationship with the 6,000-pound deflection being twice that of the 3,000 and the 9,000-pound deflections being three times that of the 3,000.

RELATING ROAD RATER RESULTS TO AASHTO STRUCTURAL NUMBERS

In 1976 the Road Rater deflection data was correlated to AASHTO flexible design guide values derated by visual examination and estimated general roadway conditions (figure 3). This correlation yielded a coefficient of 0.874.[1] Road Rater data from 1976 through 1983 has continued to support the relationship between Road Rater deflections and AASHTO structural layer coefficients (table 1). Most of the AASHTO structural layer coefficients were developed at the AASHO Road Test in 1961. The Iowa DOT has assigned a portland cement concrete coefficient of 0.50 for "new" conditon pavements. Using the AASHTO structural layer coefficients, the Road Rater deflection data is being utilized to determine resurfacing[3] needs to meet particular traffic demands.

IOWA DOT PROGRAM FOR DETERMINING SUBGRADE SUPPORT VALUES

The Iowa DOT subgrade support program principles are taken from Louisiana Highway Research.[4] In the Iowa DOT program, however, only the sensor at the load and the sensor one foot from the load are used to determine subgrade support values. The surface curvature index (SCI) is defined as the deflection of sensor 1 minus the deflection of sensor 2. A linear relationship of the sensor 1 deflection in mils is used as the X axis (figure 4), with a linear relationship of SCI divided by the sensor 1 deflection as the Y axis. Soils data was used to determine the K values of most roadway sections tested in 1982. This data was used to superimpose a logrithmic scale of K values on approximately a 45^{o} angle in relationship to the X and Y axis. A substantial amount of data that has been collected has continued to support the validity of this subgrade support value program.

LONG TERM MONITORING PROGRAM

The Iowa DOT has established 21 sections, including rigid, composite and flexible pavements for consideration in a long term monitoring program. Road

FIGURE 2

COMPARISON OF THE IOWA DOT ROAD RATER DEFLECTION AND THE FHWA THUMPER DEFLECTION

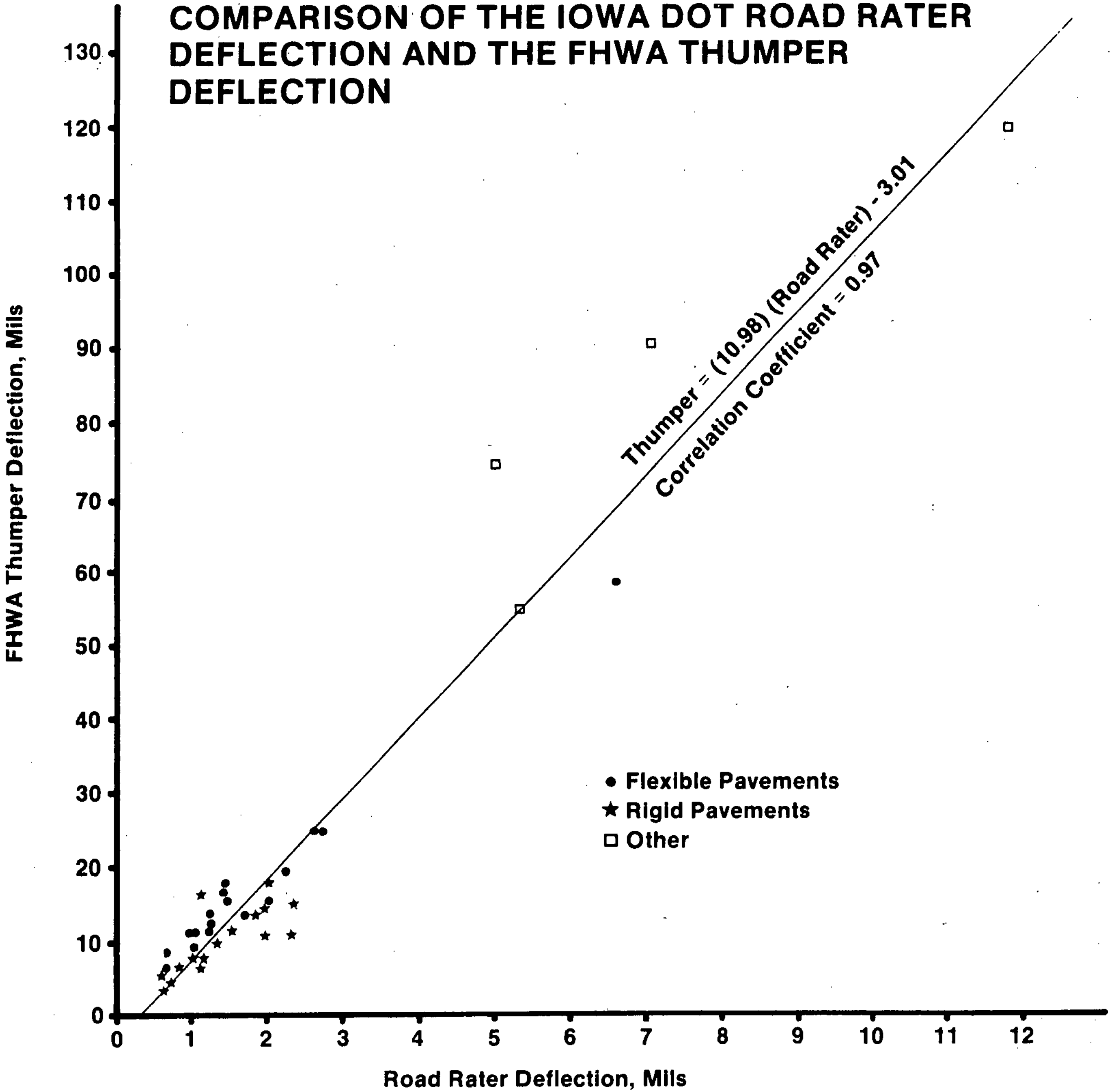


Figure 3

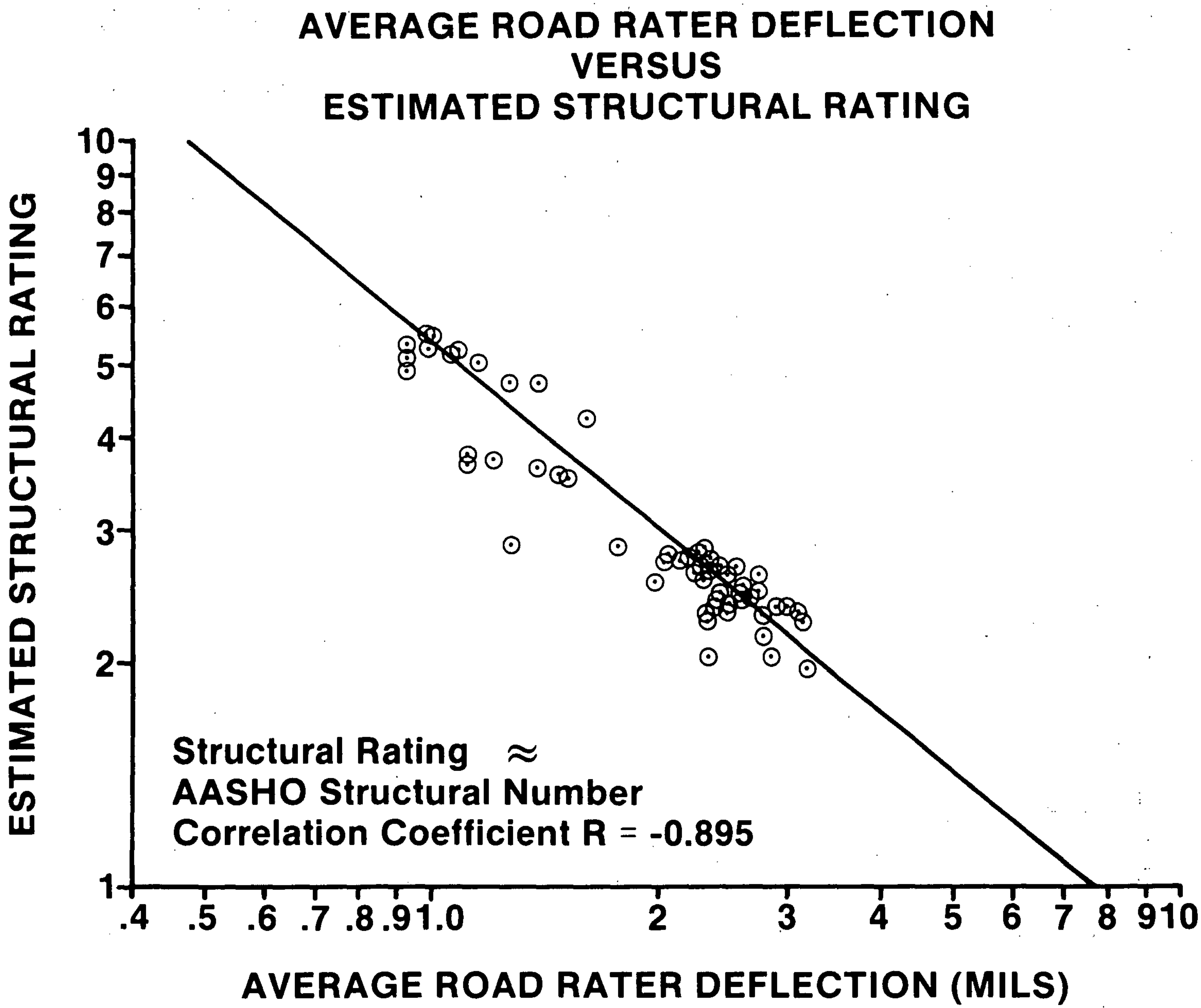

AVERAGE ROAD RATER DEFLECTION
VERSUS
ESTIMATED STRUCTURAL RATING
ESTIMATED STRUCTURAL RATING
10
9
8
7
6
5
4
3
2
1
Structural Rating ≈
AASHO Structural Number
Correlation Coefficient R = -0.895
.4
.5
.6
.7
.8
.9
1.0
2
3
4
5
6
7
8
9
10
AVERAGE ROAD RATER DEFLECTION (MILS)

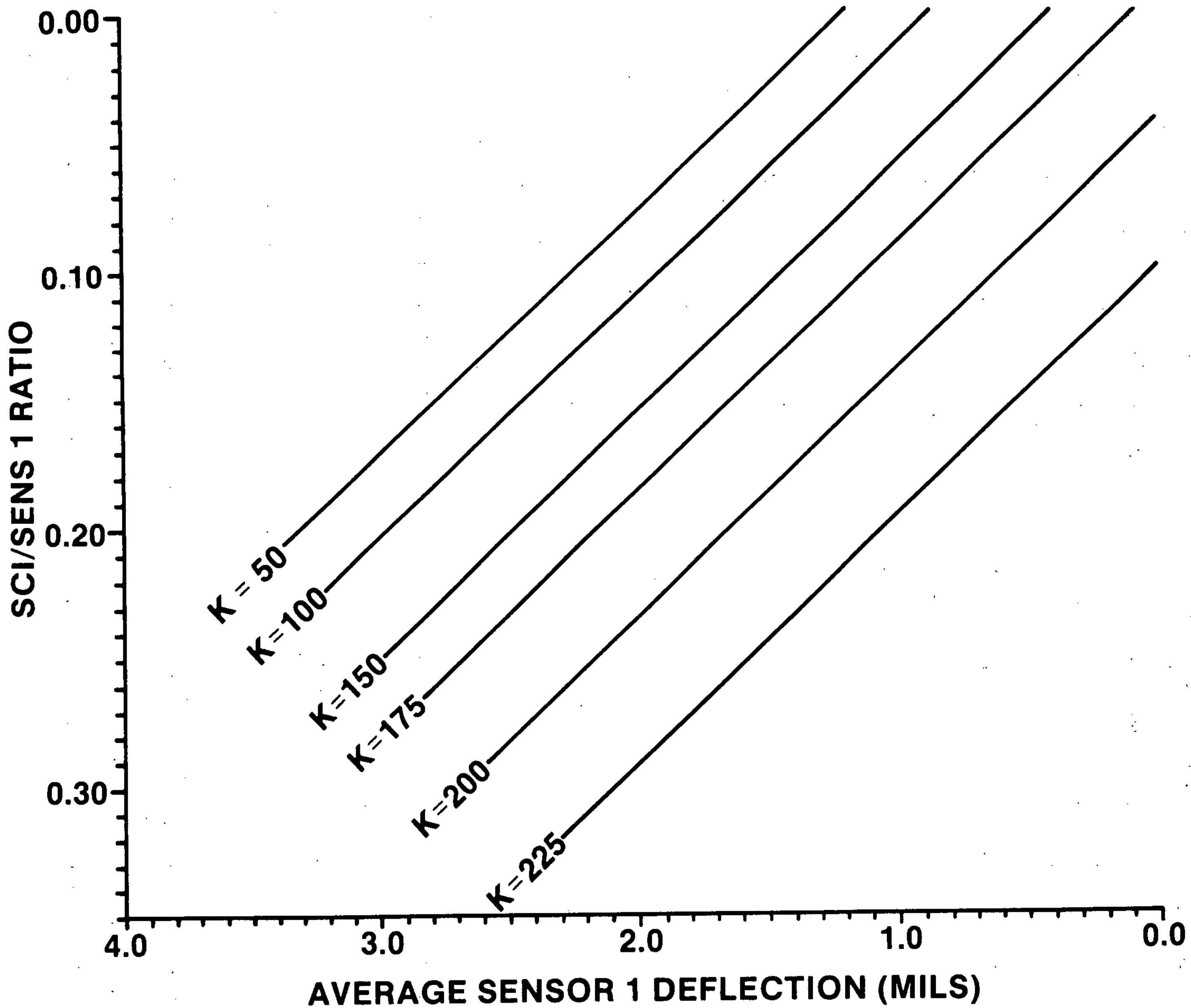
TABLE I STRUCTURAL LAYER COEFFICIENTS

Component	Coefficient
Surface Course	
Portland Cement Concrete	0.50
Type A Asphalt Cement Concrete	0.44*
Type B Asphalt Cement Concrete	0.44*
Type B Asphalt Cement Concrete Class 2	0.40
Inverted Penetration	0.20
Base Course	
Type A Binder Placed as Base	0.40
Type B Asphalt Cement Concrete Base Class I	0.38
Type B Asphalt Cement Concrete Base Class II	0.30
Asphalt Treated Base Class I	0.34*
Bituminous Treated Aggregate Base	0.23
Asphalt Treated Base Class II	0.26
Cold-Laid Bituminous Concrete Base	0.23
Cement Treated Granular (Aggregate) Base	0.20*
Soil-Cement Base	0.15
Crushed (Graded) Stone Base	0.14*
Macadam Stone Base	0.12
Portland Cement Concrete Base (New)	0.50
Old Portland Cement Concrete	0.40
Subbase Course	
Soil-Cement Subbase	0.10
Soil-Lime Subbase	0.10
Granular Subbase	0.10*
Soil-Aggregate Subbase	0.05*

*Indicates coefficients taken from AASHTO Interim Guide for the Design of Flexible Pavement Structures.

Figure 4

SOIL SUPPORT K VALUES FOR RIGID AND COMPOSITE PAVEMENTS FROM ROAD RATER DEFLECTION BASINS



Rater structural data is being obtained annually from all 21 sections. The strength and condition of all pavements were determined by coring. An analysis including moisture content was made of the soil samples taken beneath the pavement at each coring location. This data has supported the validity of our subgrade support determination program for information obtained during the spring period from the time all frost is out through June 15. Fall information indicates higher, more uniform values than were anticipated.

THE EFFECT OF LONGITUDINAL DRAINS ON SUBGRADE SUPPORT VALUES

The subgrade support values have been determined for many Iowa DOT roadways. Only a limited number of the roadways tested have continuous longitudinal drains. Another significant factor in the subgrade support value is the type of the soil on the particular roadway. This also limits the comparisons that can be made in regard to subgrade support values. Many sections of Iowa's interstate system received subgrade treatment of the top 24" of a selected glacial clay. We have four Interstate 80 projects with continuous drains with more or less similar subgrade soils which may be used to compare subgrade support values (tables 2 and 3). Longitudinal drains have been placed on an eastbound section of one portion of Interstate 80. No drains have been placed in the westbound roadway. The average subgrade support value for the eastbound roadway is a K value of 170, while the K value for the westbound roadway is 125 (table 2). Thus, showing the benefit of the longitudinal drains. It can be noted, however, that some K values in the westbound roadway exceed a corresponding value in the eastbound roadway. This would indicate that there are some areas where longitudinal drains do not contribute a significant benefit.

Table 2

POTTAWATTAMIE CO.
INTERSTATE 80

EASTBOUND 30" Deep Drains		WESTBOUND No Drains	
Milepost	**Subgrade Support Value K**	**Milepost**	**Subgrade Support Value K**
34.00	175	34.00	215
34.45	210	34.40	145
34.70	200	34.80	50
35.00	145	35.15	95
35.40	185	35.60	170
36.00	220	36.00	160
36.30	105	36.30	155
36.40	185	36.60	155
36.90	195	36.90	190
37.20	185	37.20	180
37.50	100	37.50	50
37.80	180	37.80	50
38.00	190	38.10	50
38.40	130	38.40	50
38.60	160	38.70	180
39.00	180	39.00	80
Avg.	170	Avg.	125
Structural Number	3.60	Structural Number	2.50

Table 3

SUMMARY OF SUBGRADE SUPPORT VALUES

County	Highway	Direction	Pavement Type	Thickness in Inches	Depth of Drains In Inches	Date Tested	Structural Number	Subgrade Support Value, K
Poweshiek	I-80	Both	PC	10	24	5-18-83	4.5	165
Pott.	I-80	WB	PC	8	None	3-2-83	2.5	125
Pott.	I-80	EB	PC	8+3	30	3-2-83	3.6	170
Cass	I-80	Both	AC over PC	3 over 10	48	3-2-83	5.2	210

The Iowa DOT began installing longitudinal subdrains at a depth of 24" in 1978. The trend in Iowa has been to deeper longitudinal drains with the present standard being 48" deep. A very limited amount of data (table 3) would indicate that the deeper longitudinal drains are providing a greater benefit to the subgrade support value. The 24" deep drains of the Poweshiek Interstate 80 project yielded a spring subgrade support value of 165. The 30" deep drains on Pottawattamie Interstate 80 yielded a K value of 170 while the 48" deep drains on Cass County Interstate 80 yielded a K value of 210. This limited amount of data would indicate that the deeper drains provide greater benefit to improvement of the subgrade support values.

REFERENCES

1. V. Marks, Dynamic Pavement Deflection Measurements, Progress Report for Project HR-178, Iowa Department of Transportation, May, 1977.

2. V. Marks, Dynamic Deflections to Determine Roadway Support Ratings, Final Report for Project HR-245, Iowa Department of Transportation, February, 1983.

3. D. Heins, Dynamic Deflections for Determining Structural Rating of Flexible Pavements, Final Report for Project HR-178, Iowa Department of Transportation, February 1979.

4. R. Kinchen and W. Temple, Asphalt Concrete Overlays of Rigid and Flexible Pavements, Final Report, Louisiana Highway Research, FHWA/LA-80/147, October, 1980.